

AD-A053 787

NAVY EXPERIMENTAL DIVING UNIT PANAMA CITY FLA

F/G 6/17

EVALUATION OF A FULL FACE MASK FOR INCORPORATION INTO THE SWIMM--ETC(U)

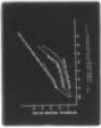
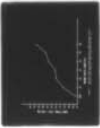
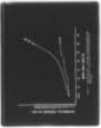
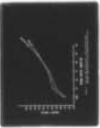
MAR 78 R K O'BRYAN

UNCLASSIFIED

NEDU-3-78

NL

1 OF 1  
AD  
A053787

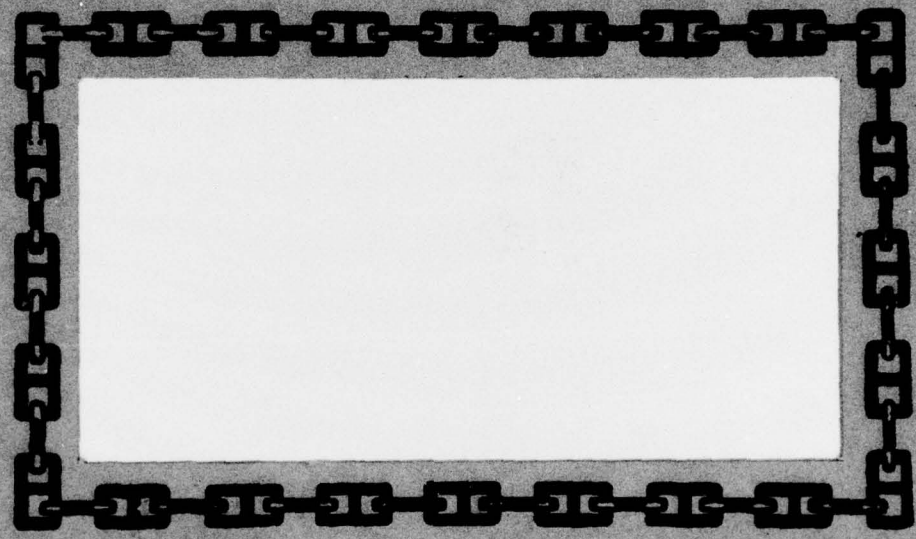


END  
DATE  
FILMED  
6 -78  
DDC

6

B.S.

AD A 053787



AD No.             
DDC FILE COPY

# NAVY EXPERIMENTAL DIVING UNIT



DDC  
RECEIVED  
MAY 11 1976  
E

DISTRIBUTION STATEMENT A  
Approved for public release  
Distribution Unlimited



DEPARTMENT OF THE NAVY  
NAVY EXPERIMENTAL DIVING UNIT  
PANAMA CITY, FLORIDA 32407

IN REPLY REFER TO:

AD A 053787

NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 3-78

EVALUATION OF A FULL FACE MASK FOR  
INCORPORATION INTO THE SWIMMER LIFE  
SUPPORT SYSTEM MK 1

By:

Robert K. O'Bryan  
LCDR, MC, USN

14 March 1978

AD No. \_\_\_\_\_  
DDC FILE COPY



Submitted by:

*Robert K. O'Bryan*

ROBERT K. O'BRYAN  
LCDR, MC, USN

Reviewed by:

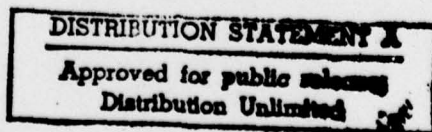
*W. H. Spaur*

W. H. SPAUR  
CAPT, MC, USN

Approved by:

*C. A. Bartholomew*

C. A. BARTHOLOMEW  
CDR, USN  
Commanding Officer



UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

| REPORT DOCUMENTATION PAGE  |  | READ INSTRUCTIONS<br>BEFORE COMPLETING FORM |
|--|--|---|
| 1. REPORT NUMBER<br>NEDU REPORT NO. 3-78   | 2. GOVT ACCESSION NO.  | 3. RECIPIENT'S CATALOG NUMBER               |
| 4. TITLE (and Subtitle)<br>EVALUATION OF A FULL FACE MASK FOR<br>INCORPORATION INTO THE SWIMMER LIFE<br>SUPPORT SYSTEM MK 1  | 5. TYPE OF REPORT & PERIOD COVERED<br>9 FINAL rept.            |   |
| 6. AUTHOR(s)<br>ROBERT K. O'BRYAN, LCDR, MC, USN   | 7. CONTRACT OR GRANT NUMBER(s)<br>14 NEDU-3-78                 |   |
| 8. PERFORMING ORGANIZATION NAME AND ADDRESS<br>NAVY EXPERIMENTAL DIVING UNIT<br>PANAMA CITY, FLORIDA 32407   | 10. PROGRAM ELEMENT, PROJECT, TASK<br>AREA & WORK UNIT NUMBERS |   |
| 11. CONTROLLING OFFICE NAME AND ADDRESS  | 12. REPORT DATE<br>11 14 Mar 78                                |   |
| 14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)  | 13. NUMBER OF PAGES<br>16 12 180                               |   |
|  | 15. SECURITY CLASS. (of this report)<br>UNCLASSIFIED           |   |
| 16. DISTRIBUTION STATEMENT (of this Report)<br>Approved for public release; distribution unlimited.  |  |   |
| 17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)   |  |   |
| 18. SUPPLEMENTARY NOTES  |  |   |
| 19. KEY WORDS (Continue on reverse side if necessary and identify by block number)<br>EVALUATION<br>FULL FACE MASK<br>SLSS MK 1<br><i>if you run into prob on F/G, see me<br/>I have at least one typed in this also</i>   |  |   |
| 20. ABSTRACT (Continue on reverse side if necessary and identify by block number)<br>The (SLSS) MK 1 with the Full Face Mask (FFM) was tested for its ability to support a diver performing sustained heavy work at operational depth. During exercise sequences, measured parameters were the divers' heart rates, oral-nasal mask differential pressures, and the oxygen and carbon dioxide fractions of inspired and expired gas. Analysis of the data clearly demonstrates that the system supports a working diver without<br>(CONTINUED) |  |   |

DD FORM 1473

EDITION OF 1 NOV 65 IS OBSOLETE  
S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

253 650

**UNCLASSIFIED**

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

20. (Continued)

→ causing either a decrement in work performance or abnormal retention of carbon dioxide. In addition, it was demonstrated that the external resistance to breathing was significantly lower with the FFM-hose assembly compared with similar data obtained with the MK VI Mod 0 mothpiece-hose assembly. ↗

|                                 |                       |                                     |
|---------------------------------|-----------------------|-------------------------------------|
| ACCESSION No.                   |                       |                                     |
| NTIS                            | White Section         | <input checked="" type="checkbox"/> |
| DOC                             | Buff Section          | <input type="checkbox"/>            |
| UNANNOUNCED                     |                       | <input type="checkbox"/>            |
| JUSTIFICATION                   |                       |                                     |
| BY                              |                       |                                     |
| DISTRIBUTION/AVAILABILITY CODES |                       |                                     |
| Dist.                           | AVAIL. and/or SPECIAL |                                     |
| A                               |                       |                                     |

**UNCLASSIFIED**

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

## ABSTRACT

The SLSS MK 1 with the Full Face Mask (FFM) was tested for its ability to support a diver performing sustained heavy work at operational depth. During exercise sequences, measured parameters were the divers' heart rates, oral-nasal mask differential pressures, and the oxygen and carbon dioxide fractions of inspired and expired gas. Analysis of the data clearly demonstrates that the system supports a working diver without causing either a decrement in work performance or abnormal retention of carbon dioxide. In addition, it was demonstrated that the external resistance to breathing was significantly lower with the FFM-hose assembly compared with similar data obtained with the MK VI Mod 0 mouthpiece-hose assembly.

EVALUATION OF A FULL FACE MASK FOR INCORPORATION  
INTO THE SWIMMER LIFE SUPPORT SYSTEM MK 1

The Swimmer Life Support System MK 1 (SLSS MK 1) is an electronically controlled, closed-circuit, mixed gas, self-contained underwater breathing apparatus. In its present configuration, the system is provided with a MK VI Mod 0 mouthpiece. With the increasing complexities of diver mission assignments, it has become of paramount importance to develop a system that provides better diver to diver communication compared to the MK VI Mod 0 mouthpiece. The Full Face Mask (FFM) was designed to provide this characteristic. It consists of an AGA mask modified to interface with the SLSS MK 1 system (Figure 1). Incorporated into the mask are a rotating shut-off valve, an oral-nasal cavity, and two one-way Koegel valves situated at the inlet and outlet of the mask assembly. These valves are three-leafed, conical valves with low resistance to gas flow ( $\pm 6$  cm H<sub>2</sub>O at 190 FSW on air with a respiratory minute ventilation of approximately 60 liters per minute).

The use of a Full Face Mask (FFM) with an oral-nasal cavity presents two potential physiological problems for a diver: (1) an oral-nasal cavity may increase ventilatory dead space and cause abnormal carbon dioxide retention, and (2) excessive external resistance of the mask and UBA to ventilation may decrease maximum work performance and/or cause carbon dioxide retention. To confirm the capability of the SLSS MK 1 with FFM to support a diver performing sustained heavy work at operational depths, this system was studied during the decompression phase of a 1500 FSW experimental saturation dive conducted at NEDU during November and December 1977. The purpose of the study was to ensure that the system would not impose a significant restriction to ventilation, or cause abnormal carbon dioxide retention during graded exercise.

#### METHODS

The experimental dive was conducted in the Ocean Simulation Facility of the Navy Experimental Diving Unit. Five experienced, U.S. Navy male divers participated in this study. Physical characteristics of the men are depicted in Table 1. All subjects performed calisthenics and runs of up to 7 km five days per week for eight weeks prior to the dive. In addition, each man performed up to 20 underwater work cycles, similar to the experimental protocol, during this pre-dive period.

Each diver wore the SLSS MK 1 closed system UBA interfaced with the Full Face Mask. The breathing hoses were 3.8 cm in diameter, compared with a diameter of 2.5 cm in the hoses presently in use. During all studies the breathing gas was Nitrogen-Oxygen, and the UBA was set to maintain an oxygen partial pressure of 0.7 ATM.

Exercise consisted of six-minute work periods, separated by four minutes of rest, on an especially modified pedal ergometer (James 1976) mounted in a horizontal attitude on a frame approximately ten feet underwater. Work began at 25 watts, and was increased by 25 watts with each successive work period until diver exhaustion occurred. The water temperature was maintained at 29°C. The study began at a depth of 150 FSW, and was conducted during standard U.S. Navy Saturation Decompression to a depth of 120 FSW.

Conventional ECG leads were fastened to the divers' chests for measurements of heart rates. Gas samples were taken from the inhalation and exhalation hoses of the underwater breathing apparatus just proximal and distal to the respective flow directing valves. The gas samples were directed at an appropriate flow rate to a mass spectrometer located outside the chamber. The Full Face Mask was instrumented with a Validyne differential pressure transducer that referenced the pressure in the oral-nasal cavity to the water pressure just outside the face plate (Figure 2). During the final minute of each exercise sequence

recordings were made of heart rate, the oxygen and carbon dioxide fractions of the inhaled and end expired gas samples, and the differential pressures recorded inside the oral-nasal mask.

## RESULTS

Figure 3 shows mean heart rates plotted against work loads at 32 FSW and at depths between 150 and 120 FSW. The heart rate, which is directly proportional to the oxygen consumption, increased in a linear fashion with increasing work loads at all depths. The plots obtained are similar, and the mean heart rates for the maximum work loads at 32 FSW and at depth were 146 and 154 respectively. If it is assumed that actual work output was 30% greater than that indicated on the ergometer (Costill 1971), or if the heart rates are correlated with values obtained during work in the dry laboratory, the estimated oxygen consumption at maximum tolerated work was in excess of 3 liters per minute (Astrand, 1970). In all studies the partial pressure of oxygen on the inspired gas varied between .6 and .9 atmospheres.

Figure 4 shows mean oral-nasal mask differential pressures versus work loads at 32 FSW and at depth. At 32 FSW, the differential pressures increased minimally from rest through the 50 watt work cycle (7 to 8 cm H<sub>2</sub>O). From

50 to 150 watts there was a near linear increase from 8 to 18 cm H<sub>2</sub>O. At depth, however, there was a linear increase in pressure from rest to 100 watts (6 cm to 16 cm H<sub>2</sub>O), following which there was an increasing rate of rise with each succeeding work cycle, with a maximum mean differential pressure of 38 cm H<sub>2</sub>O recorded during the 150 watts work cycle.

Figure 5 shows mean end tidal carbon dioxide versus work at depths between 150 and 120 FSW. There was a near linear rise in end tidal CO<sub>2</sub> from a mean of 37.5 mmHg at rest to a mean of 46.7 mmHg at 150 watts. At no time did significant levels of CO<sub>2</sub> appear in the inhaled gas.

#### DISCUSSION

The amount of work man can perform in a dry environment usually is limited by the function of the cardiovascular system. In diving, however, ventilation often proves to be the primary limitation. If a diver's ability to increase effective ventilation with increasing ventilatory requirements is diminished, the level of carbon dioxide in the blood and tissue rises. As this occurs, a number of physiological responses may occur, some of which can prove hazardous, or even fatal to a diver, especially when diving in a closed circuit UBA. Among these are: (1) decreased mental and physical performance, (2) potentiation of inert gas narcosis, decompression sickness, and oxygen toxicity; and (3) progressive somnolence

possibly resulting in unconsciousness. It is obvious, then, that ventilatory restrictions to diver work performance play a major role in the design criteria for any piece of underwater breathing apparatus.

Restrictions to adequate ventilation usually result from one of two factors. First, elevated breathing gas density increases the resistance to gas flow in the airways of the lungs and in the breathing apparatus. This can result in either an excessive work of breathing with a subsequent deterioration of useful work output, or a reduction in adequate ventilation accompanied by  $\text{CO}_2$  retention. If the restriction is sufficiently severe, both a reduction in work output and carbon dioxide retention may occur. The second factor that may lead to inadequate ventilation is elevated carbon dioxide levels in the inspired gas. In such a situation, the diffusion gradient for  $\text{CO}_2$  between the blood and breathing gas is reduced, and in order to maintain normal  $\text{CO}_2$  transport out of the body, there must be a corresponding increase in ventilation. If the diver is unable to increase ventilation, carbon dioxide will be retained. In an apparatus such as the SLSS MK 1 with FFM, elevated ambient  $\text{CO}_2$  could occur with either an inefficient carbon dioxide absorbent bed or an excessively large dead space. It was the purpose of this study to determine if the MK 1 SLSS with FFM could support a diver performing heavy work, equivalent to an oxygen consumption of 3 liters

per minute, without causing an unacceptably large restriction to ventilation with resultant decreased work performance, or carbon dioxide retention.

Figure 4, a graphic depiction of oral-nasal differential pressure versus work load, represents the external resistance to breathing that the diver experienced during work. As can be seen, the peak pressures recorded at depth rose from a value of 6 cm H<sub>2</sub>O at rest to a maximum of 38 cm H<sub>2</sub>O during the 150 watts work cycle. While these values for external resistance are moderately high, it is important to note that the divers were able to complete work cycles equivalent to an oxygen consumption in excess of 3 liters per minute without any decrement in work performance compared to surface work. In addition, Figure 6 compares the differential pressures obtained at depth in this study with the oral-nasal differential pressures obtained during graded exercise studies utilizing the SLSS MK 1 with the MK VI Mod 0 mouthpiece, conducted at a depth of 130 FSW during an experimental saturation dive at NEDU in April of 1976 (Zumrick). This comparison reveals quite clearly that the differential pressures produced during graded exercise utilizing the FFM-hose assembly at 150 FSW were nearly one half the pressures produced using the MK VI Mod 0 mouthpiece-hose assembly at 130 FSW.

Figure 5 shows that the mean end tidal  $P_{CO_2}$ , which reflects arterial blood  $P_{CO_2}$ , rose from a mean value of 37.5 mmHg at rest to a mean of 46.7 mmHg at 150 watts. This rise in end tidal  $P_{CO_2}$  is normal for a diver at depth breathing a dense gas during exercise. It can be concluded, therefore, that neither the external resistance to ventilation, nor the dead space of the Full Face Mask assembly were excessive.

#### SUMMARY

The breathing characteristics of the SLSS MK 1 with the Full Face Mask were studied at 150 to 120 FSW during the decompression phase of a 1500 FSW experimental dive. It was clearly demonstrated that the apparatus can support a diver performing sustained heavy exercise at operational depths without either a decrement in work performance or abnormal carbon dioxide retention. In addition, it was shown that the differential pressures produced utilizing the FFM-hose assembly were approximately one-half of those recorded with the MK VI Mod 0 mouthpiece-hose assembly.

# BIBLIOGRAPHY

1. Astrand, P. and K. Rodahl. 1970. Textbook of Work Physiology, McGraw-Hill Book Company, New York.
2. Costill, D. L. 1971 Energy requirements during exercise in water. J. Sports Medicine and Physi. Fitn. 11(2):87-92.
3. James, T. W. 1976. Modified Collins pedal-mode ergometer, development and medical tests. U.S. Navy Exp. Diving Unit Report 1-76.
4. Zumrick, J.L. 1978. Manned Evaluation of The Swimmer Life Support System MK 1 (SLSS MK 1). U.S. Navy Experimental Diving Unit Report (In press).

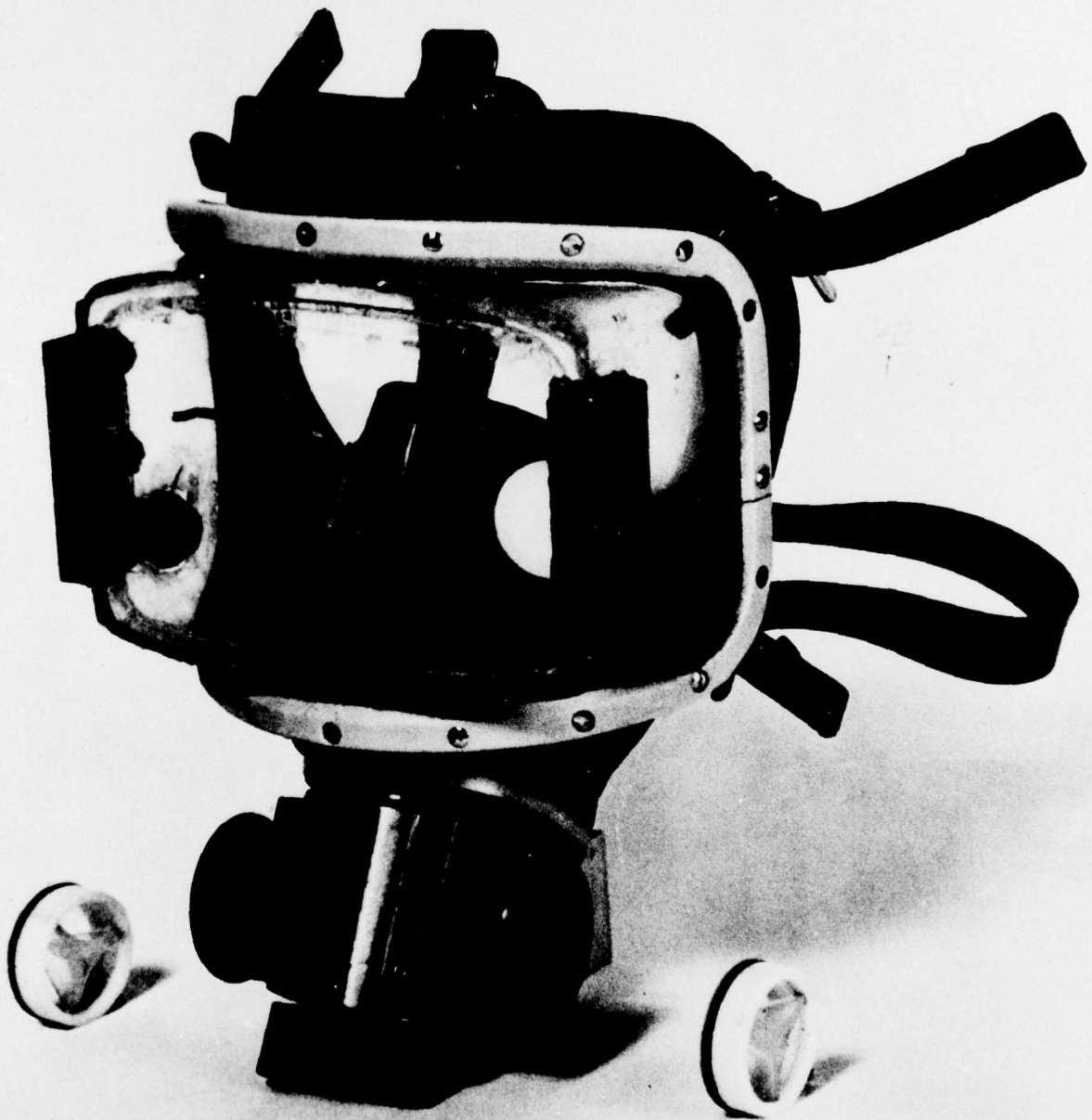


FIGURE 1: Full Face Mask Showing  
3-leafed Directional Flow Valves.

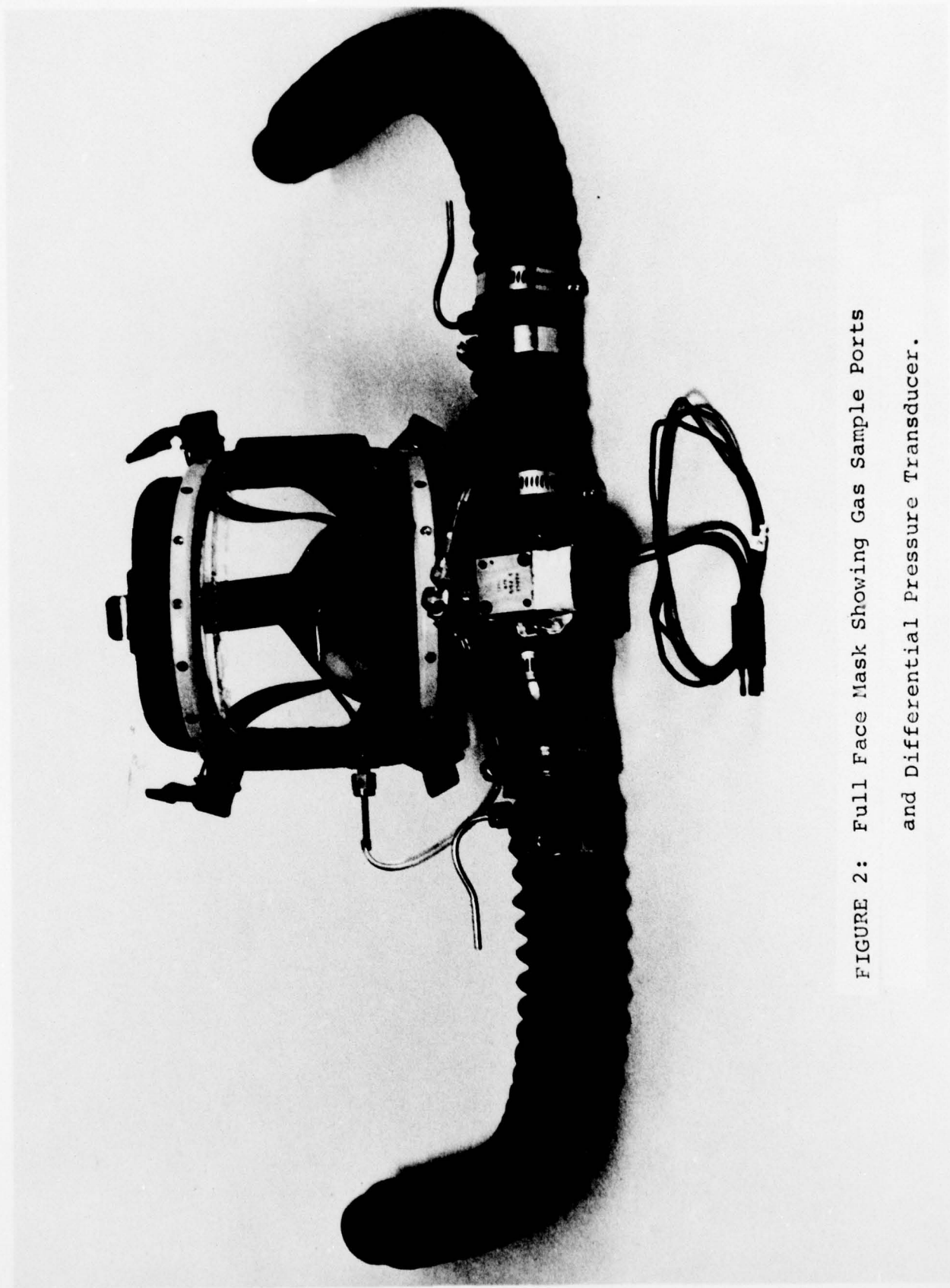


FIGURE 2: Full Face Mask Showing Gas Sample Ports  
and Differential Pressure Transducer.

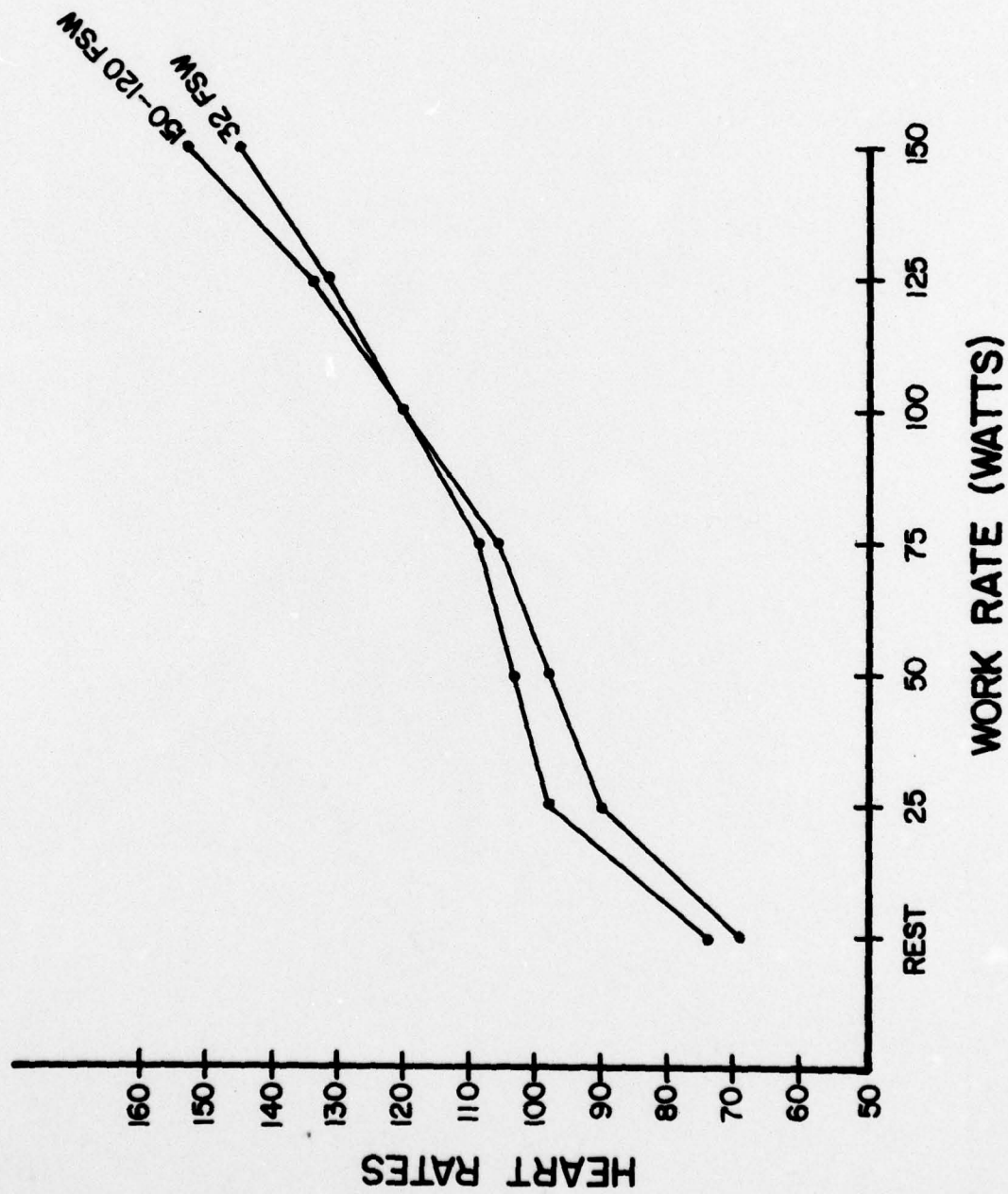


Figure 3. Full face mask with SLSS MK 1: Heart rate with graded exercise - mean values for divers completing each work rate

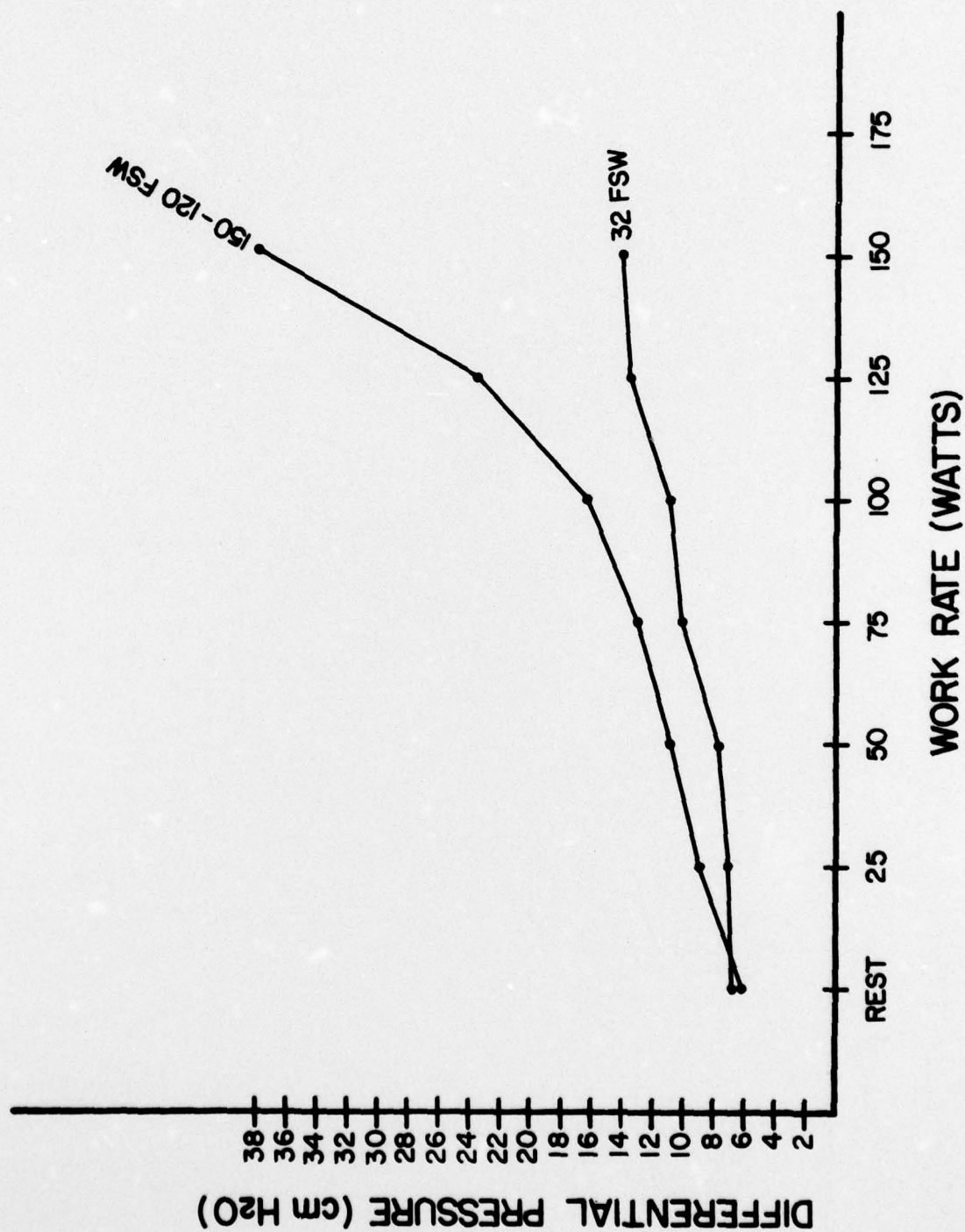


Figure 4. FFM with SLSS MK 1: Oral nasal differential pressure with graded exercise - mean values for divers completing each work rate

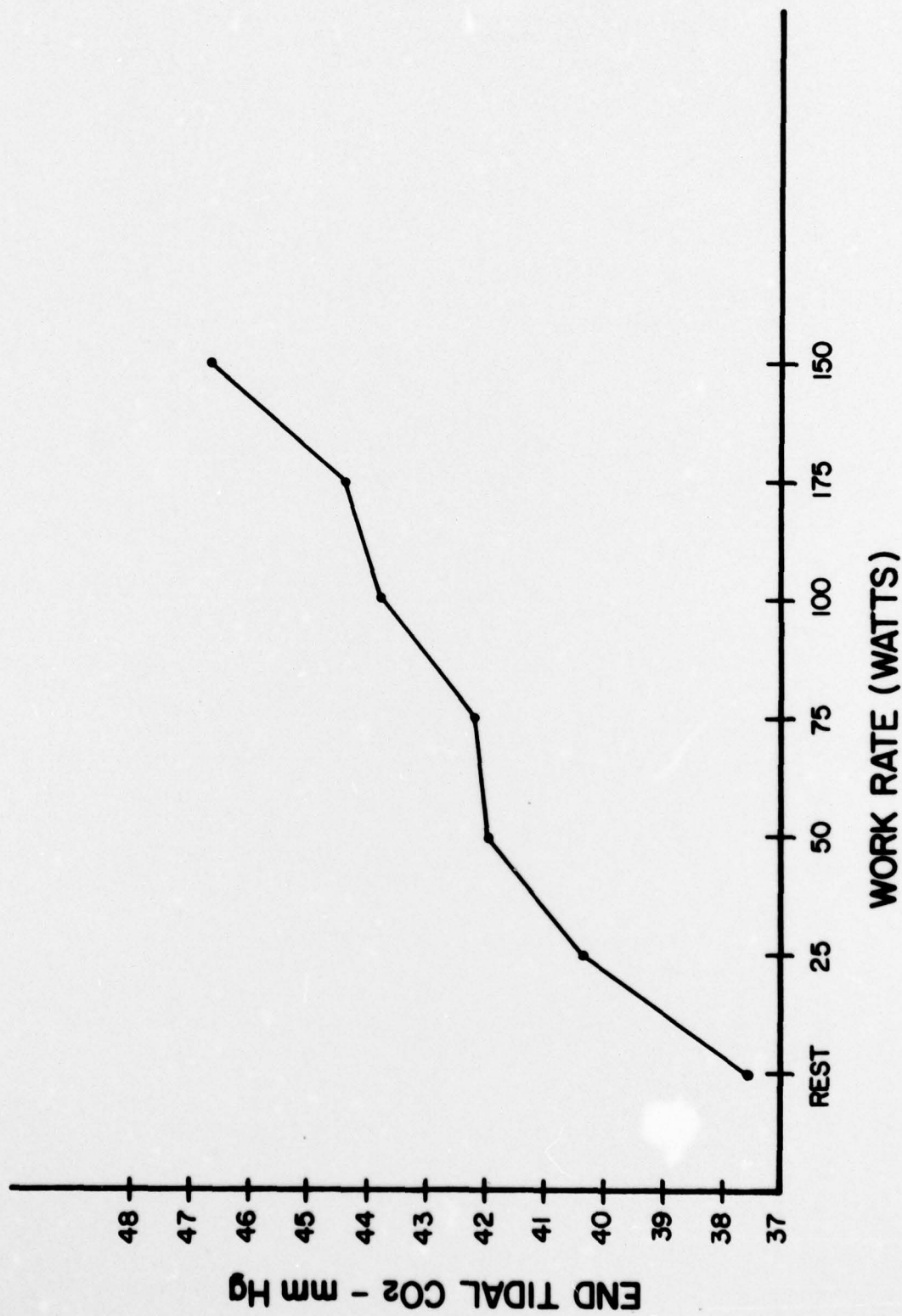


Figure 5. End tidal  $P_{CO_2}$  with graded exercise at depths between 150 and 120 FSW - mean values for divers completing each work rate

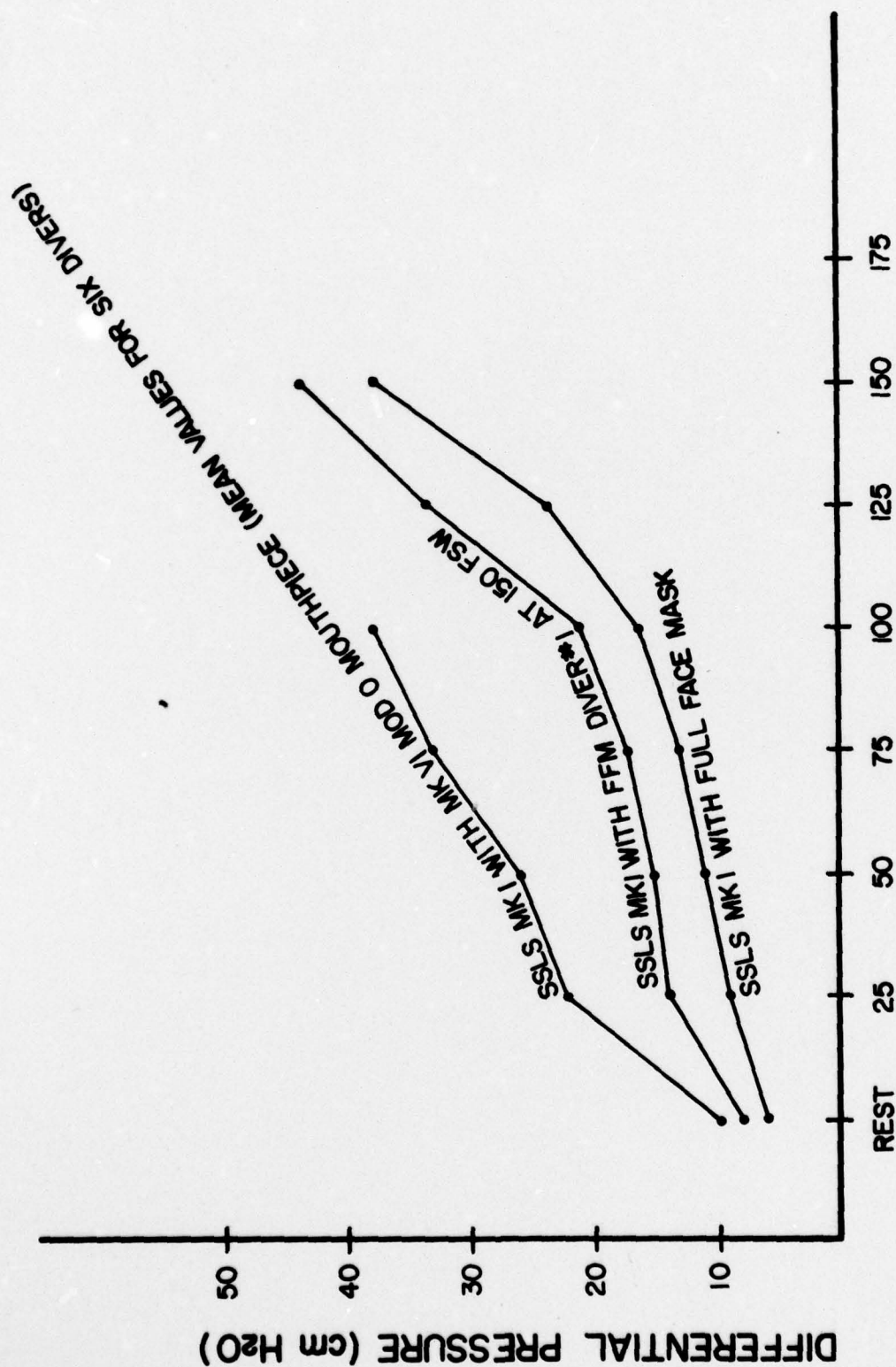


Figure 6. Comparison of SLSS MK I with MK VI MOD 0 mouthpiece at 130 FSW to SLSS MK I with face mask at depths between 150 and 120 FSW and at 150 FSW